# TRANSMISIJE IN POGONI V INDUSTRIJI

# UČNI NAČRT PREDMETA/COURSE SYLLABUS

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| **Predmet:** | Transmisije in pogoni v industriji |
| **Course title:** | INDUSTRIAL POWER-TRAINS |
| **Članica nosilka/UL Member:** | UL FS |

| **Študijski programi in stopnja** | **Študijska smer** | **Letnik** | **Semestri** | **Izbirnost** |
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| Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni | Konstruiranje industrijskih sistemov (smer) | 3. letnik | 1. semester | obvezen |

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| **Univerzitetna koda predmeta/University course code:** | 0563471 |
| **Koda učne enote na članici/UL Member course code:** | 3054-V |

| **Predavanja /Lectures** | **Seminar /Seminar** | **Vaje /Tutorials** | **Klinične vaje /Clinical tutorials** | **Druge oblike študija /Other forms of study** | **Samostojno delo /Individual student work** | **ECTS** |
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| 30 | | 30 | | | 40 | 4 |

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| **Nosilec predmeta/Lecturer:** | Jernej Klemenc, Simon Oman |
| **Vrsta predmeta/Course type:** | Izbirni strokovni predmet/Elective specialised course |

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| **Jeziki/Languages:** | Predavanja/Lectures: | Slovenščina |
| | Vaje/Tutorial: | Slovenščina |

**Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** **Prerequisites:**

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| Izpolnjevanje pogojev za vpis v Visokošolski strokovni študijski program I. stopnje Strojništvo - Projektno aplikativni program. | Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme. |

| **Vsebina:** | **Content (Syllabus outline):** |
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| 1. Predavalnje: Bilanca sil in moči v industrijskih pogonih:<br>- Upori in bremena kot ponori moči;<br>- Pogonski stroj kot izvor moči;<br>- Transmisija kot sestav komponent od izvora do ponora moči.<br>2. Predavanje: Vrste prenosa moči in možnosti za rekuperacijo energije:<br>- Mehanski prenos moči;<br>- Hidravlični prenos moči;<br>- Električni prenos moči.<br>3. Predavanje: Vrste pogonskih strojev in njihove značilnosti:<br>- Karakteristika idealnega pogonskega stroja;<br>- Elektromotorji;<br>- Motorji z notranjim zgorevanjem.<br>4. Predavanje: Gonila za mehanski prenos moči:<br>- Kdaj potrebujemo različna prestavna razmerja v gonilih;<br>- Diskretna prestavna razmerja;<br>- Zvezno nastavljiva prestavna razmerja.<br>5. Predavanje: Gonila za mehanski prenos moči:<br>- Značilnosti gonil z oblikovnim prenosom moči;<br>- Izgube in samozapornost gonila;<br>- Značilnosti gonil s tornim prenosom moči.<br>6. Predavanje: Pogonski sistemi z več izvori ali ponori moči:<br>- Princip delitve moči iz enega izvora;<br>- Princip sumacije moči iz več izvorov;<br>- Distribuirani pogoni;<br>- Problem sinhronizacije tokov moči.<br>7. Predavanje: Osnove planetnih gonil kot mehanskih sumatorjev ali delilnikov moči:<br>- Vrste in oznake planetnih gonil;<br>- Grafična določitev notranjih prestav enostavnega planetnega gonila;<br>- Navori na gredeh planetnega gonila. | 1. Lecture: Force and power balance in industrial power-trains:<br>- Resistors and loads as power consumers;<br>- Driving engine as power source;<br>- Transmission as an assembly of components between power source and power consumption.<br>2. Lecture: Power-transmisson types and possibilities for energy recovery:<br>- Mechanical transmissions;<br>- Hydraulic transmissions;<br>- Electric transmissions.<br>3. Lecture: Driving engine types and their output characteristics:<br>- Characteristics of an ideal power source;<br>- Electric motors;<br>- Internal combustion engines.<br>4. Lecture: Mechanical transmission systems:<br>- When different transmission ratios are needed in gearboxes;<br>- Discreete transmission ratios;<br>- Continously variable transmissions.<br>5. Lecture: Mechanical transmission systems:<br>- Characteristics of transmissions with geometric power transmission;<br>- Power losses and self-locking;<br>- Characteristics of transmissions with frictional power transmission.<br>6. Lecture: Transmission systems with multiple power sources and outputs:<br>- Principle of power splitting from one source;<br>- Principle of power summation from multiple sources;<br>- Distributed transmissions;<br>- Problem of power-flow synchronisation.<br>7. Lecture: Introduction to planetary gears as mechanical power summators or splitters: |

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| 8. Predavanje: Osnove planetnih gonil kot mehanskih sumatorjev ali delilnikov moči:<br>- Wolfova shema;<br>- Zunanje prestave planetnega gonila;<br>- Kotalna in sklopna moč planetnega gonila.<br>9. Predavanje: Osnove planetnih gonil kot mehanskih sumatorjev ali delilnikov moči:<br>- Kombinirana planetna gonila.<br>10. Predavanje: Primeri mehanskih menjalnikov:<br>- Ročni sekvenči menjalnik;<br>- Ročni menjalnik s predležno gredjo;<br>- Avtomatski menjalnik z dvojno sklopko.<br>11. Predavanje: Avtomatski menjalnik s pretvornikom navora:<br>- Ravigneaux planetno gonilo;<br>- Hidravlični pretvornik navora;<br>- Izgube pri prenosu moči.<br>12. Predavanje: Usmerjanje navora v transmisiji z razvejišči:<br>- Diferencialna gonila v transmisiji z razvejišči;<br>- Uporaba visko-sklopke v transmisiji z razvejišči;<br>- Vektoriranje navora.<br>13. Predavanje: Električni hibridni prenosniki moči:<br>- Zaporedni hibridni pogon;<br>- Vzporedni hibridni pogon;<br>- Kombinirani hibridni pogon.<br>14. Predavanje: Hidravlični prenosniki moči:<br>- Hidrostatični prenosnik moči;<br>- Hidrodinamični prenosnik moči.<br>15. Predavanje: Kombinirani mehansko-hidravlični prenosnik moči:<br>- Razcep in združenje tokov moči;<br>- Zveznost prestavnega razmerja;<br>- Inverzija smeri vrtenja in blokada hidravličnega toka moči;<br>- Izkoristek transmisije. | - Types and designations of planetary gears;<br>- Graphical determination of internal (stable) gear ratios for a simple planetary gear;<br>- Torques in shafts of the planetary gear.<br>8. Lecture: Introduction to planetary gears as mechanical power summators or splitters:<br>- Wolf’s scheme;<br>- Outer gear ratios of the planetary gear;<br>- Rolling and swirching power in the planetary gear.<br>9. Lecture: Introduction to planetary gears as mechanical power summators or splitters:<br>- Combined planetary gears.<br>10. Lecture: Examples of mechanical gearboxes:<br>- Manual sequential gearbox;<br>- Manual conventional gearbox;<br>- Automatic dual-clutch gearbos.<br>11. Lecture: Automatic gearbox with torque converter:<br>- Ravigneaux planetary gear;<br>- Hydraulic torque converter;<br>- Power losses during power transmission.<br>12. Lecture: Torque vectoring in transmission with multiple branches:<br>- Differential gear in transmission with multiple branches;<br>- Application of visco-clutch in transmission with multiple branches;<br>- Torque vectoring.<br>13. Lecture: Electric hybrid power-trains:<br>- Serial hybrid drive;<br>- Parallel hybrid drive;<br>- Combined hybrid drive.<br>14. Lecture: Hydraulic power-trains:<br>- Hydrostatic hydraulic transmission;<br>- Hydrodynamic hydraulic transmission.<br>15. Lecture: Combined hydro-mechanical transmission systems:<br>- Power splitting and summation;<br>- Continously variable transmission;<br>- Inverter of angular velocity and |

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| | locking of hydraulic power flow;<br>- Power efficiency. |

**Temeljna literatura in viri/Readings:**

Klemenc J. Dinamika vozil – učbenik. Ljubljana: UL, Fakulteta za strojništvo, 2019.

Wittel H., Jannasch D., Vossiek J., Spura C. Roloff/Matek Maschinenelemente – 23. Auflage. Springer Vieweg, 2017.

Granzow C. ZF Vector Drive – better driving dynamics and driving safety through Torque Vectoring. Praesentation Praktischer Entwurf mechatronischer Systeme, Karlsruhe 13.12.2013.

Flašker J., Pehan S. Prenosniki moči : učbenik. UM, Fakulteta za strojništvo, 2005.

| **Cilji in kompetence:** | **Objectives and competences:** |
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| Cilji:<br><br>Spoznati osnovne principe uravnoteženja moči pri industrijskih pogonih.<br><br>Spoznati različne variante transmisij in pogonov v industriji.<br><br>Spoznati kriterije za izbiro posameznih tipov industrijskih pogonov.<br><br>Spoznati delovne principe, koncipiranje in oblikovanje osnovnih mehanskih industrijskih pogonov.<br><br>Spoznati delovne principe naprednih industrijskih pogonov v smislu njihove uporabe.<br><br>Kompetence:<br><br>S1-PAP: Sposobnost uporabe pridobljenega znanja s področja industrijskih pogonov v praksi.<br><br>S10-PAP: Sposobnost strokovnega sporazumevanja in pisnega izražanja z obravnavanega področja.<br><br>S13-PAP: Sposobnost iskanja virov znanja, selekcija najdenih virov in uporaba tako pridobljenega znanja pri svojem delu.<br><br>P1-PAP: Razume fizikalne zakone in pojave, na katerih temelji funkcija mehanskih, hidravličnih in električnih pogonov.<br><br>P8-PAP: Obvlada osnovna in potrebna specifična znanja v izbrani študijski | Objectives:<br><br>To learn basic principles of power balancing in industrial power-trains.<br><br>To learn different types of transmission systems in the industry.<br><br>To train usage of the relevant criteria for selecting different types of industrial power-trains.<br><br>To learn work principles, conceptualisation and design of basic mechanical industrial power-trains.<br><br>To learn working principles of complex industrial power-trains from the viewpoint of ther application.<br><br>Competences:<br><br>S1-PAP: The ability to use the attained knowledge of industrial power-trains in the practice.<br><br>S10-PAP: The ability to communicate professionally and express oneself in writing.<br><br>S13-PAP: The ability to find sources of knowledge, select among the available resources and use the knowledge acquired for one's work.<br><br>P1-PAP: Understanding the laws of physics and the phenomena behind the operating principles of mechanical, hydraulic and electric power-trains. |

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| smeri (analiza in sinteza industrijskih pogonov). | P8-PAP: Mastering the basic and required specific knowledge from the selected study (analysis and synthesis of industrial power-trains). |

| **Predvideni študijski rezultati:** | **Intended learning outcomes:** |
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| Znanja:<br>Z1: Poglobljeno strokovno teoretično in praktično znanje na določenem področju, podprto s širšo teoretično in metodološko osnovo:<br>- Razumevanje zveze med potrebami in viri moči v industrijskih pogonih.<br>- Razumevanje teoretičnih in praktičnih osnov za izbiro, koncipiranje in oblikovanje nezahtevnih industrijskih pogonov.<br>- Razumevanje delovanja naprednih industrijskih pogonov na nivoju njihove aplikacije.<br>Spretnosti:<br>S1.1 Izvajanje kompleksnih operativno-strokovnih opravil, ki vključujejo tudi uporabo metodoloških orodij:<br>- Preračun zunanjih karakteristik mehanskih gonil.<br>- Izdelava projektne ali nabavne dokumentacije za sestavne elemente industrijskih gonil.<br>S1.2 Obvladovanje zahtevnih, kompleksnih delovnih procesov ob samostojni uporabi znanja v novih delovnih situacijah:<br>- Vodenje vzdrževalnih posegov različne pogonske sisteme v industriji. | Knowledge:<br>Z1: Thorough professional theoretical and practical knowledge in a selected field of expertise that is supported with a broad theoretical and methodological basis:<br>- Understanding relationship power sources and needs in industrial power-trains.<br>- Understanding theoretical and practical basis for selection, conceptualisation and design of simple industrial power-trains.<br>- Functional understanding of complex industrial power-trains at usage level.<br>Skills:<br>S1.1 Executing complex operationa-professional tasks that incorporate usage of methodological tools:<br>- Calculating output characteristics of mechanical power-trains.<br>- Preparation of project or procurement documentation for components of industrial power-trains.<br>S1.2 Mastering demanding and complex work processes by independent usage of knowledge in new working situations:<br>- Managing maintenance activities for different industrial power-trains. |

| **Metode poučevanja in učenja:** | **Learning and teaching methods:** |
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| P1: Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.<br><br>P3: Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri.<br><br>P4: Laboratorijske vaje z namenskimi didaktičnimi pripomočki (prirejeni zobniški menjalniki in diferencialna gonila). | P1: Auditorial lectures with solving selected field-specific theoretical and applied use cases.<br><br>P3: Auditorial exrecises, in which theoretical content from the lectures is supplemented with practical examples.<br><br>P4: Laboratory exercises with special-purpose didactic devices (modified gearboxes and differential gears).<br><br>P8: Making and presenting applied |

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| P8: Izdelava in predstavitev aplikativnih seminarskih nalog.<br>P15: Uporaba video vsebin kot priprava na predavanja in vaje. | seminar exercises.<br>P15: Application of videos for preparations to the lectures and exercises. |

| **Načini ocenjevanja:** | **Delež/ Weight** | **Assessment:** |
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| Teoretična znanja (pisni kolokviji in izpit z opcijskim ustnim zagovorom). | 50,00 % | Theoretical knowledge (written colloquia and exam with an optional oral examination). |
| Aplikativne seminarske naloge (poročila s predstavitvami). | 10,00 % | Applied seminar exercises (reports with presentations). |
| Laboratorijske vaje (poročila). | 10,00 % | Laboratory exercises (reports). |
| Avditorne vaje (poročila). | 10,00 % | Auditorial exercises (reports). |
| Pisni preskus praktičnega znanja, osvojenega na vajah. | 20,00 % | Written examination of practical knowledge that was acquired in exercises. |

**Reference nosilca/Lecturer's references:**

Jernej Klemenc:

MIKLAVEC, Matej, **KLEMENC, Jernej**, KOSTANJEVEC, Andrej, FAJDIGA, Matija. Fatigue strength of a hybrid joint formed between a PA6-GF60 polymer matrix and a S420MC steel insert. Materials & design, Oct. 2013, vol. 51, str. 493-500, ilustr., doi: 10.1016/j.matdes.2013.04.058.

**KLEMENC, Jernej**, FAJDIGA, Matija. Simulating a Gaussian random process by conditional PDF. Engineering computations, 2011, vol. 28, no. 5, str. 540-556, doi: 10.1108/02644401111141000.

**KLEMENC, Jernej**, FAJDIGA, Matija. Improved modelling of the loading spectra using a mixture model approach. International journal of fatigue, 2008, letn. 30, št. 7, str. 1298-1313. http://dx.doi.org/10.1016/j.ijfatique.2007.08.024.

**KLEMENC, Jernej**, FAJDIGA, Matija. Determining the material parameters of a polyurethane foam with a differential ant-stigmergy algorithm. V: The automobile in the second decade : sharing all energy solutions : final programme and exhibition catalogue. València: Universitat Politècnica. 2011, str. E21-1-E21-9.

ŠKRLEC, Andrej, FRANKO, Mitja, OMAN, Simon, ZOBEC, Peter, NAGODE, Marko, **KLEMENC, Jernej**. Numerical fatigue-life prediction for a trailing arm BMW-UKL : final report. Ljubljana: Faculty of Mechanical Engineering, 2016. 133 f.

Simon Oman:

**OMAN, Simon**, FAJDIGA, Matija, NAGODE, Marko. Estimation of air-spring life based on accelerated experiments. Materials & design, ISSN 0264-1275, 2010, vol. 31, iss. 8, str. 3859-3868, doi: 10.1016/j.matdes.2010.03.044.

**OMAN, Simon**, NAGODE, Marko. The influence of piston shape on air-spring fatigue life. Fatigue & fracture of engineering materials & structures, ISSN 8756-

758X, 2018, vol. 41, iss. 5, str. 1019-1031, ilustr. http://onlinelibrary.wiley.com/doi/10.1111/ffe.12748/epdf, doi: 10.1111/ffe.12748.

GOSAR, Aleš, NAGODE, Marko, **OMAN, Simon**. Continuous fatigue damage prediction of a rubber fibre composite structure using multiaxial energy-based approach. Fatigue & fracture of engineering materials & structures, ISSN 8756-758X, Jan. 2019, vol. 42, iss. 1, str. 307-320, ilustr. https://onlinelibrary.wiley.com/doi/epdf/10.1111/ffe.12908, doi: 10.1111/ffe.12908.

**OMAN, Simon**, NAGODE, Marko. Določitev dobe trajanja zračnih vzmeti = Air springs service life determination. Svet strojništva, ISSN 1855-6493, nov. 2016, letn. 5, št. 4/5, str. 14-20, ilustr.

ŠKRLEC, Andrej, FRANKO, Mitja, **OMAN, Simon**, ZOBEC, Peter, NAGODE, Marko, KLEMENC, Jernej. Numerical fatigue-life prediction for a trailing arm BMW-UKL : final report. Ljubljana: Faculty of Mechanical Engineering, 2016. 133 f., graf. prikazi.